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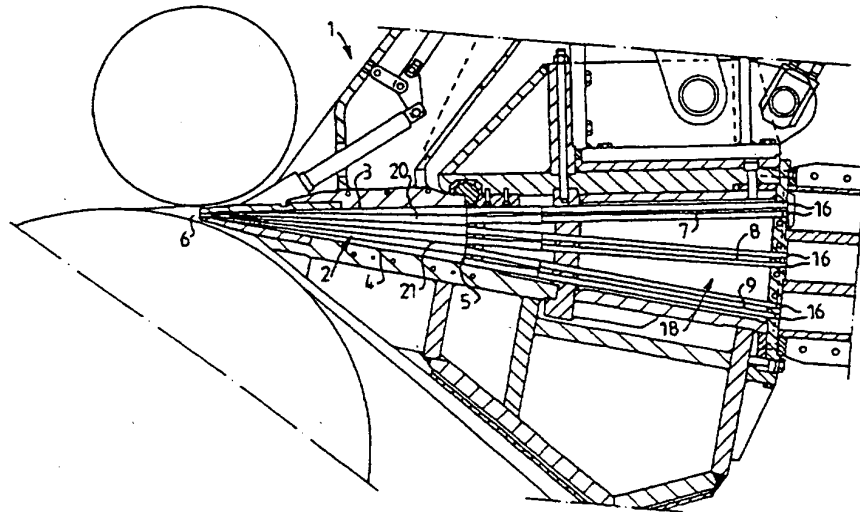
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(54) Title: A MULTILAYER HEADBOX FOR A PAPERMAKING MACHINE



(57) Abstract

A multilayer headbox for a papermaking machine which comprises a slice chamber having an upstream inlet and a downstream outlet. A tube bank comprising a plurality of straight tubes is located upstream of the slice chamber. In the slice chamber, at least one machine-wide separator vane is subdividing the slice chamber for the production of multilayered fibrous webs. The separator vane may be a tapered glass fiber reinforced epoxy resin vane or composed of an upstream steel section of constant thickness and a downstream tapered section of glass fiber reinforced epoxy resin. The separator vane has a stiffness, which for at least 70 % of its length is higher than the stiffness of a 1 mm thick reference sheet of a material having a modulus of elasticity of 2100 MPa. In the slice chamber, there is also a plurality of machine-wide turbulence generating elements.

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A MULTILAYER HEADBOX FOR A PAPERMAKING MACHINE

FIELD OF THE INVENTION

The present invention relates to a multilayer headbox for ejecting stock into a forming section of a papermaking machine for forming a fibrous web.

BACKGROUND OF THE INVENTION

In the art of papermaking, stock is ejected from a slice chamber of a headbox into a forming section of a papermaking machine. The forming section may comprise a single forming fabric, a forming fabric in combination with a felt, or a pair of forming fabrics. In the forming section, water drains from the stock through a forming fabric so that a fibrous web is formed. In order to produce a fibrous web having several layers, it is a common and well-known practice to employ, in the headbox, machine-wide separator vanes that divide the slice chamber into separate sections such that through each section, stock may be passed which is of a composition different from the composition of the stock being passed through an adjacent section. For example, one section may be used for the passage of stock containing short fibers, while an other section may be used for the passage of stock containing long fibers.

During the forming of a fibrous web, it is important that flocculation is avoided and that the web will get a uniform basis weight profile. When a fibrous web having several layers is produced, it is important that the web has a good and uniform layer purity and a good coverage. In the context of this application, layer purity should be understood as the degree to which the separate layers of the fibrous web are able to retain their respective composition, i. e. the degree to which mixing of the layers is avoided, while coverage should be understood as the degree to which each layer of the fibrous web has a uniform basis weight in the cross machine direction. If the formed web has a poor coverage, this will have an adverse effect on the uniformity of the layer purity, which will render the operation of the papermaking machine more difficult since a uniform layer purity is required during subsequent phases of the papermaking process, e. g. during creping when the creping doctor will be adjusted in accordance with the surface properties of the fibrous web on the side adhering to the drying cylinder. It is also a common practice that chemicals are added to the process in order to facilitate creping and the quantity and composition of the chemicals will depend on the surface qualities of the fibrous web. A web of non-uniform layer purity will render impossible an optimization of the papermaking process since adjustment of the creping doctor and the adding of chemicals will depend on the surface qualities of the fibrous web. Furthermore, it is desirable that the paper web should have a uniform strength across the web (i. e. in the cross machine direction) and a web having poor coverage will not be of uniform strength across the web. Therefore, there is a need for a multilayer headbox which is able to produce a

multilayered web which has a good and uniform layer purity and a good coverage and which is also free of flocculations and has a uniform basis weight.

SUMMARY OF THE INVENTION

- 5 The object of the invention is to provide a multilayer headbox, which is able to produce a layered fibrous web that has a good and uniform layer purity and that is free of flocculations and has a uniform basis weight. The object of the invention is attained by the present invention which is directed to a multilayer headbox for a papermaking machine. The headbox comprises a slice chamber which has an upstream inlet where stock is intended to enter the
- 10 slice chamber and a downstream outlet through which stock is intended to pass from the slice chamber to a subsequent forming section of the papermaking machine. The slice chamber has an intended straight main direction of flow of the stock from the inlet of the slice chamber to the outlet of the slice chamber. The slice chamber has a top wall, a bottom wall and two side walls. The top and bottom walls converge in the straight main direction of flow of the stock
- 15 through the slice chamber. The headbox further comprises a tube bank located upstream of the slice chamber in the direction of flow of the stock. The tube bank comprises a plurality of straight tubes. The tubes of the tube banks are arranged in vertically spaced tube bank sections such that each tube bank section in the tube bank is arranged to feed stock exclusively intended for one layer of the fibrous web to be formed. In each tube bank section,
- 20 the tubes are arranged in vertically spaced rows, the rows extending in a cross machine direction. The tube bank can thus be described as comprising a plurality of straight tubes where the tubes are arranged in separate vertically spaced rows. Each tube has an upstream inlet end and a downstream outlet end from which stock is intended to pass into the inlet of the slice chamber such that the tube bank with its tubes forms a passage through which stock
- 25 is intended to pass from the upstream inlet end of the tubes to the inlet of the slice chamber. The passage has a straight main direction of flow of the stock which coincides with the intended straight main direction of flow of the stock in the slice chamber so that all the way from the upstream inlet end of the tubes to the downstream outlet of the slice chamber, the stock will flow in one and the same straight main direction of flow.
- 30 According to the invention, the headbox comprises at least one, but possibly two or three, machine-wide separator vane or vanes in the slice chamber. The separator vane (or vanes) subdivides the slice chamber such that a multilayered fibrous web may be formed. The separator vane (or vanes) has an upstream end and a downstream end and extend in the intended direction of flow of the stock and has a thickness in the vertical dimension. At the
- 35 inlet to the slice chamber, interposed between the vertically spaced tube bank sections in the tube bank, elongate ledges are provided that extend in a cross machine direction and connect the tube bank sections to each other. The upstream end of the separator vane (or of each

separator vane) is fastened to one of the elongate ledges interposed between the vertically spaced tube bank sections in the tube bank.

In accordance with the invention, the headbox further comprises, in the slice chamber, a plurality of machine-wide turbulence generating elements extending in the direction of flow of the stock. Each turbulence generating element has an upstream end and a downstream end. The upstream end of each turbulence generating element is interposed between the vertically spaced rows of tubes in a tube bank section and fixed between the rows. The turbulence generating elements can be realized in the form of vanes with uneven, i. e. rough surface but the inventors have found that also vanes with a smooth surface will have a turbulence generating effect which is sufficient for the purpose of the invention.

According to an important aspect of the invention, the separator vanes are made to have a certain minimum stiffness in the cross machine direction for at least 7/10 of the length of the separator vane. The stiffness of the separator vane, is chosen to be on average at least 36 Nm and on at least 7/10 of the length of each separator vane, at least 7 Nm. In tests carried out by the inventors, it was found that the separator vane (or vanes) should have an average stiffness which is at least 180 times higher than the stiffness of a 1 mm thick reference sheet or reference plate of a material having a modulus of elasticity of about 2100 MPa and that for at least 7/10 of the length of the vane (or vanes), the stiffness should be at least 35 times higher than for the reference sheet or reference plate.

In a preferred embodiment of the invention, the separator vane (or separator vanes) is a homogenous element made of glass fiber reinforced epoxy resin and is tapered all the way from its upstream end to its downstream end such that its thickness decreases continuously from its upstream end to its downstream end.

In an other embodiment of the invention, the separator vane (or vanes) is divided into an upstream section of constant thickness in the vertical dimension and a downstream section which is tapered such that its thickness decreases in the direction of flow of the stock. In that embodiment, the upstream section will have an upstream end which is the same as the upstream end of the separator vane and a downstream end to which the downstream section is fixed. In the same way, the downstream section will have an upstream end fixed to the upstream section of the separator vane and a downstream end which is the same as the downstream end of the separator vane. At the point where the upstream section is fixed to the downstream section, i. e. at the transition between the upstream section and the downstream section, there is a machine-wide step due to the fact that at the point where the upstream section is fixed to the downstream section, the downstream section has a thickness in the vertical dimension which is less than the thickness in the vertical dimension of the upstream section. The upstream section might be of steel while the downstream section is preferably of glass fiber reinforced epoxy resin.

In that embodiment of the invention where the separator vane(s) is a homogenous element tapered all the way from its upstream end to its downstream end, the separator vane(s) has a surface smoothness, or R_a value, which is smaller than or equal to $0.4 \mu\text{m}$.

5 In the embodiment of the invention where the separator vane(s) is divided into an upstream section and a tapered downstream section, the tapered downstream section has surface smoothness, or R_a value, which is smaller than or equal to $0.4 \mu\text{m}$.

10 In both embodiments of the invention, the thickness in the vertical dimension of the separator vane is less than 0.7 mm at the downstream end of the separator vane(s). Preferably, the thickness in the vertical dimension should be about 0.5 mm . At the downstream end of the separator vane, the thickness in the cross machine direction will of course be subject to a degree of variation. The inventors have found that the thickness at the downstream end should not vary more than 0.05 mm . When the thickness of the separator vane is chosen to be 0.5 mm , this will therefore result in a separator vane which, at its downstream end, has a thickness of $0.5 \text{ mm} \pm 0.05 \text{ mm}$ or $0.45 \text{ mm} - 0.55 \text{ mm}$.

15 Providing a separator vane, or separator vanes, having a surface smoothness which is, at least at a downstream end of the separator vane(s), smaller than $0.4 \mu\text{m}$ and having a thickness at its downstream end which is less than 0.7 mm contributes to the achievement of a good layer purity. With regard to layer purity, it can be desirable to make the downstream end of the separator vane (or vanes) even thinner. However, the inventors have found that when the tip of a vane (the downstream end of the vane) is thinner than 0.5 mm , this makes the tip to
20 weak and to likely to be broken by fatigue. Therefore, the inventors have found that a thickness of about 0.5 mm is preferable. In order to achieve that the layer purity will also be uniform, it is necessary that the formed web will also have a good coverage.

25 The inventors have found that the following features will contribute to the achievement of a good coverage:

A) The passage formed by the tube bank has the same main direction of flow of the stock as the slice chamber such that, all the way from the inlet of the tubes in the tube bank to the outlet of the slice chamber, the stock will be able to flow in one and the same main direction of flow.

30 B) The slice chamber comprises turbulence generating elements.

C) The separator vane (or vanes) are stiff in the cross machine direction.

D) The thickness variation of the separator vane at its downstream end is no more than 0.05 mm .

35 The inventors have found that when the headbox is formed as a straight flow headbox, i. e. when the stock flows in one and the same main direction of flow all the way from the inlet end of the tubes in the tube bank to the outlet of the slice chamber, this will have an advantageous effect on the coverage of the subsequently formed fibrous web and that this

advantageous effect can be reinforced by providing turbulence generating elements in the slice chamber.

Headboxes are known, e.g. from U. S. Patent No. 4,941,950 (Sanford), where the stock is forced to change its direction of flow when it enters the slice chamber. The inventors of the present invention have recognized that such a design will have a disadvantageous effect on the coverage of the fibrous web and therefore, the inventors have designed the headbox of the present invention as a straight flow headbox such that the stock will not change its direction of flow as it enters the slice chamber.

The inventors have also found that, in order to obtain a good coverage, the separator vane, or separator vanes, should be stiff in the cross machine direction. The inventors have found that one important cause for poor coverage is insufficient stiffness of the separator vane(s) in the cross machine direction. If the stiffness of the vane(s) in the cross machine direction is insufficient, this may cause flexing of the vane(s) such that, in the cross machine direction, the layers of the subsequently formed web will not have a uniform basis weight in the cross machine direction, i. e. the coverage will be poor. It is also desirable that the stiffness in the machine direction is high if a fibrous web which is uniform in the machine direction is to be obtained. The separator vanes employed in the present invention are of such a design that their thickness decreases towards the tip of the vanes, i. e. the thickness of a vane is less at the downstream end of the vane than at the upstream end of the vane. For this reason, the stiffness of the vane is not uniform. Instead, the stiffness of each vane decreases towards the downstream end of the vane. Therefore, the stiffness of a separator vane according to the present invention has to be calculated at different locations of the vane. Bending stiffness per meter length of a plate having a thickness h , a modulus of elasticity E , can be calculated according to the formula

$$S = Eh^3/12(1-\nu^2)$$

where S is stiffness and ν is the Poisson ratio. This is the stiffness definition which is used in the context of this patent application. For steel, the Poisson ratio will normally be about 0.3 while for glass fiber reinforced resin, the Poisson ratio can be given as about 0.15. The stiffness is thus proportional to the product of the modulus of elasticity and the plate thickness.

The invention has two different embodiments and in both embodiments, the material or materials used for the separator vane (or separator vanes) is isotropic in the sense that it has the same properties in both the machine direction and the cross machine direction (but not necessarily in the vertical dimension). Therefore, the stiffness of a separator vane, such as stiffness is defined in the context of this application, will be the same in both the machine direction and the cross machine direction. One way of increasing the stiffness is to increase the thickness of the vane(s). However, at the downstream end of the vane(s), the thickness of the vane(s) must be small, preferably less than 0.7 mm and preferably about 0.5 mm, in order to obtain good layer purity. However, the inventors have found that it is sufficient that an

upstream part of the separator vane(s) is of high stiffness and that if only the downstream end of the separator vane(s) is of a smaller stiffness, the relatively small stiffness of the downstream end of the separator vane(s) will not be able to cause any significant reduction of the good coverage of the fibrous web. It is to be noted that in both embodiments of the invention, the material or materials used for the separator vane (or vanes) is isotropic in the sense that it has the same properties in both the machine direction and the cross machine direction. For this reason, the stiffness at any given location along the length of a separator vane, as stiffness is defined in the context of this application, will be the same in both the machine direction and the cross machine direction.

10 In tests carried out by the inventors, different separator vanes have been compared with a 1 mm thick reference sheet or reference plate of a polycarbonate material having a modulus of elasticity of about 2100 MPa. The Poisson ratio of the material used for the reference sheet was about 0.3. The stiffness of the reference sheet, as stiffness is defined in the context of this patent application, is the same from the upstream end to the downstream end and can be
15 calculated as being $2100 \text{ MPa} * (0,001\text{m})^3 / 12(1 - 0.3^2) = 0.2 \text{ Nm}$.

The tests carried out by the inventors showed that when the 1 mm thick reference sheet was used as a separator vane, the formed fibrous web had unsatisfactory coverage. However, the inventors found that satisfactory results with regard to coverage can be obtained when the separator vane(s) has a stiffness in the cross machine direction which, for at least 7/10 (70%)
20 of its length is at least 35 times greater than the stiffness of a 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of about 2100 MPa. The vanes that were found to give satisfactory results with regard to the coverage of the formed fibrous web had an average stiffness which was at least 180 times higher than the stiffness of the reference sheet.

25 The expression "average stiffness" should here be understood as the stiffness value which is obtained by choosing at least 11 points on the separator vane evenly spaced from each other in the machine direction, adding the stiffness values of the different points and dividing the result by the number of points. The expression "for at least 7/10 of its length....35 times greater than a 1 mm thick reference sheet of a material having a modulus of
30 elasticity of about 2100 MPa" should here be understood as meaning that the stiffness at the upstream end of the separator vane(s) is much higher than a 1 mm thick sheet (or plate) of a polycarbonate material having a modulus of elasticity of about 2100 MPa and that the stiffness gradually decreases towards the downstream end of the separator vane(s) but that for at least 7/10 (70%) of its length, the vane(s) has a stiffness at least 35 times greater than a 1 mm thick
35 reference sheet (or reference plate) of a polycarbonate material having a modulus of elasticity of about 2100 MPa so that no more than 3/10 of the separator vane, at the downstream end of the separator vane, has a stiffness less than 35 times that of a 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of about 2100 MPa.

In the first and preferred embodiment of the invention, a separator vane (or separator vanes) is used which is tapered such that its thickness decreases linearly from its upstream end to its downstream end. Preferably, the material used for this vane is an isotropic glass fiber reinforced epoxy resin having a modulus of elasticity of 25,000 MPa. At the root (the upstream end), this vane may have a thickness of 3.8 mm. The thickness gradually decreases towards the tip (the downstream end of the vane) where the thickness will be about 0.5 mm. For the material chosen, the Poisson ratio is 0.15. The stiffness at the upstream end of this vane will be, as stiffness is defined in the context of this application ($S = Eh^3/12(1-\nu^2)$), $25000 \text{ MPa} * (0.0038 \text{ m})^3/12(1 - 0.15^2) = 117.2 \text{ Nm}$. Towards the downstream end of the separator vane, the stiffness gradually decreases but for 7/10 (70%) of the length of the separator vane, the stiffness is at least 7 Nm and thus at least 35 times higher than the stiffness of the 1 mm thick reference sheet. The average stiffness in this case will be about 36 Nm and thus at least 180 times higher than the stiffness of the 1 mm thick reference sheet. This choice of stiffness value for the separator vane(s) significantly contributes to the achievement of a good coverage of the subsequently formed fibrous web.

In that embodiment of the invention where the separator vane(s) is composed of two separate sections, the upstream section will have a substantially constant stiffness all the way from the upstream end of the vane(s) to the point where the downstream section of the separator vane(s) is fastened to the upstream section. The downstream section will then have a gradually decreasing stiffness. The upstream section of constant thickness may be of steel and have a modulus of elasticity of 203,000 MPa and a thickness of about 12 mm. The Poisson ratio (ν) in this case is about 0.3. The length of the upstream steel section may be around 500 mm. The stiffness of this section, as stiffness is defined in the context of this patent application, can thus be calculated according to the formula $S = E*h^3/12(1-\nu^2)$ as being 32123 Nm. The downstream section has a linearly decreasing thickness which goes from 3.8 mm at its upstream end to about 0.5 mm at its downstream end. The material chosen for the downstream section is glass fiber reinforced epoxy resin having a modulus of elasticity of 25000 MPa and the Poisson ratio (ν) is about 0.3. The length of the downstream section may be around 330 mm, giving the separator vane a total length of 830 mm. The stiffness of the upstream end of the downstream section, as stiffness is defined in the context of this patent application, can be calculated as being 117.2 Nm. For at least 7/10 of its length, the stiffness of this separator vane will be at least 57 Nm and therefore more than 280 times stiffer than the 1 mm thick reference sheet. The average stiffness will be about 20449 Nm and therefore much more than 180 times higher than the stiffness of the reference sheet. In this embodiment of the invention, the machine-wide step at the transition between the upstream section of the separator vane(s) and the downstream section of the vane(s) will also contribute to the achievement of good coverage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view of a headbox according to one embodiment of the present invention.

FIG. 2 is a cross sectional view similar to FIG. 1 showing in greater detail parts of a headbox according to a second embodiment of the invention.

FIG. 3 is a cross sectional view of a multilayered fibrous web having good layer purity and good coverage.

FIG. 4 is a cross sectional view of a multilayered fibrous web having a poor layer purity.

FIG. 5 is a cross sectional view of a multilayered web having good layer purity but poor coverage.

FIG. 6 shows a comparative study of the stiffness of two different separator vanes compared with the stiffness of a 1 mm thick reference sheet of a material having a modulus of elasticity of about 2100 MPa.

FIG. 7 is a cross sectional view showing a separator vane according to a preferred embodiment of the invention.

FIG. 8 is a cross sectional view showing a separator vane according to a second embodiment of the invention.

FIG. 9 is a cross sectional view similar to FIG. 1 showing in greater detail some parts of the slice chamber.

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIG. 1, a headbox 1 is shown. The headbox has a slice chamber 2 which is limited by a top wall 3 and a bottom wall 4 and a pair of side walls (not shown). The slice chamber has an upstream inlet 5 and a downstream outlet 6 and during operation, the stock will pass from the inlet 5 to the outlet 6 such that the slice chamber can be described as having an intended straight main direction of flow from the upstream inlet 5 to the downstream outlet 6. Upstream of the slice chamber in the intended direction of flow of the stock, there is a tube bank 18. The tube bank 18 comprises several sections 7, 8, 9 of tubes that are vertically spaced from each other. Each tube bank section in the tube bank comprises a plurality of straight tubes 10, 11, 12, 13, 14, 15 and the tubes in each tube bank section are arranged in separate vertically spaced rows, the rows extending in a cross machine direction. Each tube has an upstream inlet end 16 through which stock is intended to enter the tube and a downstream outlet end 17 through which stock is intended to pass into the slice chamber at the inlet or inlet end 5 of the slice chamber 2. The tube bank 18 with its tubes thus forms a passage through which stock is intended to pass from the upstream inlet end of the tubes to the inlet of the slice chamber 2 and into the slice chamber 2. The passage constituted by the tube bank 18 has a straight main direction of flow which coincides with the straight main

direction of flow of the stock in the slice chamber or, in other words, when the stock leaves the tube bank 18 and enters the slice chamber 2, the stock will not change its direction of flow (the flow of stock will, of course, converge but the main direction of flow will remain unchanged). The stock will thus flow in one and the same main direction of flow all the way from the upstream inlet end of the tubes in the tube bank to the downstream outlet of the nozzle chamber. The inventors have found that the straight flow of the stock all the way through the tube bank and the slice chamber contributes to a good coverage of the fibrous web and thereby also to a greater uniformity of the layer purity such that the formed fibrous web will have a cross section similar to the one indicated in FIG. 3. In FIG. 3, a cross section of a 3-layered paper web is shown where the top and bottom layers may consist of short fibers while the middle layer may consist of long fibers. If the stock is instead forced to change its direction of travel as it enters the slice chamber, this will tend to result in a fibrous web of inferior coverage such that the formed fibrous web will have a cross section similar to the one indicated in FIG. 5. As can be seen in FIG. 5, the layers are well separated but each layer does not have a uniform basis weight. FIG. 4 shows a cross section of a paper web where the layers are mixed together with each other such that layer purity is poor.

At the inlet of the slice chamber 2, interposed between the vertically spaced rows of tubes in the tube bank and connecting the tube rows to each other, the headbox is provided with elongate ledges 19 that extend in a cross machine direction. The elongate ledges 19 make possible the attachment of machine-wide separator vanes 20, 21 that subdivide the slice chamber into separate channels for the production of a multilayered fibrous web. In FIG. 1, two separator vanes are shown but it is to be understood that the invention could equally well be applied to a headbox having only one separator vane or possibly three separator vanes. The separator vanes 20, 21, extend in the intended direction of flow of the stock and each of the machine-wide separator vanes 20, 21 has an upstream end 22 and a downstream end 23 and the upstream end of each separator vane is fastened to one of the elongate ledges interposed between the vertically spaced rows of tubes in the tube bank 18.

According to the invention, the separator vanes are given a stiffness which is, on average, at least 36 Nm and which is, on a part of the separator vane stretching from the upstream end of the separator vane up to at least 7/10 (70 %) of the length of the separator vane, has a stiffness which is at least 7 Nm. The separator vanes will thereby have a stiffness which is, on average, at least 180 times greater than a 1 mm thick reference sheet or reference plate of a polycarbonate material having a modulus of elasticity of 2100 MPa and which, on a part of the separator vane stretching from the upstream end of the separator vane up to at least 7/10 of the length of the separator vane, has a stiffness in the cross machine direction which is at least 35 times greater than the stiffness of a 1 mm thick reference sheet or reference plate of a polycarbonate material having a modulus of elasticity of 2100 MPa.

In the preferred embodiment of the invention, each separator vane is made of glass fiber reinforced epoxy resin having a modulus of elasticity of about 25,000 MPa and has a thickness calculated to result in an average stiffness of the separator vane in the cross machine direction which is at least 180 times higher than the stiffness of a 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of 2100 MPa and a stiffness which, from the upstream end of the separator vane over at least 7/10 (70%) of the length of the separator vane, is at least 35 times higher than the stiffness of a 1 mm thick reference sheet (or reference plate) of a polycarbonate material having a modulus of elasticity of 2100 MPa.

With reference to FIG. 6, a comparative stiffness study between a 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of 2100 MPa and two different separator vanes in accordance with the present invention is shown. In FIG. 6, curve 1 shows (as a reference) the stiffness of a 1 mm thick reference sheet (or reference plate) of a polycarbonate material having a modulus of elasticity of 2100 MPa while curve 2 shows the stiffness of a tapered separator vane of glass fiber reinforced epoxy resin according to the preferred embodiment of the present invention as compared to that of the 1 mm thick reference sheet. The average value of the stiffness is, in this case, about 36.2 Nm and thus about 181 times higher than the reference value of the 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of 2100 MPa and has, for 7/10 of the length of the vane, a stiffness of at least 7.1 Nm and thus 35.5 times higher than the stiffness of a 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of 2100 MPa. In this embodiment of the invention, the separator vane has a thickness at its upstream end of approximately 3.8 mm. The thickness decreases linearly towards the downstream end of each separator vane, the length of which may be on the order of 800 - 850 mm, (the inventors envisage that 830 mm is a suitable choice of separator vane length) and at the downstream end of the vane, the thickness will be on the order of approximately 0.5 mm. The inventors have found that, in order to achieve good layer purity, the thickness of the vanes should not exceed 0.7 mm at the downstream end of the separator vanes. The inventors envisage that the thickness at the downstream end may be around 0.5 mm and that the variation in the thickness should be no greater than 0.05 mm. The thickness is chosen to be lower than 0.7 mm in order to achieve a good layer purity. In order to ensure that the service life of the vanes is not unduly short, a thickness of about 0.5 is preferred. With regard to the coverage, it is preferable that the thickness variation is no greater than 0.05 mm. The material used for the separator vanes is isotropic in the sense that it has the same mechanical properties in both the machine direction and the cross machine direction. It is to be noted that the mechanical properties in the vertical dimension are not necessarily the same as in the machine direction and the cross machine direction. The material used is therefore not necessarily isotropic in the sense that it has the same mechanical properties in all directions.

With reference to FIG. 2, and FIG. 8, a second embodiment of the invention is shown. In this embodiment of the invention, each separator vane is composed of a machine-wide upstream section 31 and a machine-wide downstream section. The upstream section 31 has an upstream end which is the same as the upstream end of the separator vane itself, and a downstream end 33 to which the downstream section 29 is fixed. The upstream section is composed of a steel plate of constant thickness while the downstream section 29 is made of glass fiber reinforced epoxy resin. The steel plate has a modulus of elasticity of 203,000 MPa and its thickness is 12 mm. The stiffness of the upstream section, as stiffness is defined in the context of this application, can thus be calculated as being 32123 Nm and therefore 160615 times higher than the stiffness of the 1 mm reference sheet. The downstream section has an upstream end 30 and a downstream end 23 common with the downstream end of the separator vane itself. The upstream end 30 of the downstream section 29 is fixed to the downstream end 33 of an associated upstream section. The downstream section has, at its upstream end, a thickness which is less than the thickness of the downstream end of the upstream section so that at the transition between the upstream section and the downstream section, there is a machine-wide step 32. The machine-wide downstream section is tapered in such a way that its thickness decreases linearly in the direction of flow of the stock and is preferably made of glass fiber reinforced epoxy resin having a modulus of elasticity of 25,000 MPa. The downstream section 29 has, at its upstream end, a thickness of 3.8 mm and the stiffness at the upstream end can be calculated as being about 117 Nm as stiffness is defined in the context of this patent application. In order to achieve a good layer purity of the fibrous web, the thickness of the downstream section is made less than 0.7 mm at the downstream end of the downstream section. The thickness at the downstream end of the downstream section may be 0.5 mm with a maximum variation of 0.05 mm such that the thickness lies in the range 0.45 mm - 0.55 mm. For good layer purity, the surface smoothness, or R_a value, of the downstream section is made to be smaller than 0.4 μm .

With reference to FIG. 6, curve 3 shows the stiffness of a separator vane according to the second embodiment of the invention compared to the stiffness of a 1 mm thick reference sheet (or reference plate) of a polycarbonate material having a modulus of elasticity of 2100 MPa. As can be seen in FIG. 3, the separator vane composed of an upstream section of constant thickness and a downstream tapered section has, during a first part of its length (the upstream section which has a constant thickness), a constant stiffness. At the transition between the upstream section and the downstream section, there is an immediate reduction of the stiffness of the separator vane and as can be seen in FIG. 6, the tapered downstream section has a gradually decreasing stiffness towards its downstream end. The average stiffness of this vane will be considerably higher than 180 times the stiffness of a 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of 2100 MPa. In fact, the average stiffness of this separator vane, as stiffness is defined in the context of this patent

application, will be 20449 Nm. During at least 7/10 of the length of the vane, the stiffness will be higher than 57.1 Nm and therefore more than 280 times higher than the stiffness of the 1 mm thick reference sheet of a polycarbonate material having a modulus of elasticity of 2100 MPa which has a stiffness of 2.1 Nm.

5 In both embodiments of the invention, the slice chamber 2 of the headbox is further provided with a plurality of machine-wide turbulence generating elements 25, 26, 27 as can be seen in FIG. 9. Each turbulence generating element is located in one of the separate flow channels formed either between the top wall 3 and a separator vane 20, 21, between two separator vanes 20, 21 or between a separator vane 20, 21 and the bottom wall 4. Each of the
10 machine-wide turbulence generating elements extends in the direction of flow of the stock and each turbulence generating element has an upstream end 34 and a downstream end 28. The upstream end 34 of each turbulence generating element 25, 26, 27 is interposed between two vertically spaced rows of tubes in the tube bank and fixed between said rows.

The invention achieves that a multilayered fibrous web can be produced which has a
15 good layer purity and a good coverage which assures that the layer purity will also be uniform. In addition, the fibrous web will have uniform strength properties across the web.

Claims

1. A multilayer headbox for a papermaking machine comprising:
- 5 a) a slice chamber having an upstream inlet where stock is intended to enter the slice chamber and a downstream outlet through which stock is intended to pass from the slice chamber to a subsequent forming section of the papermaking machine, the slice chamber having a straight main direction of flow of the stock from the inlet of the slice chamber to the outlet of the slice chamber, the slice chamber further having a top wall and a bottom wall, the top and bottom wall converging in the straight main direction of flow of the stock,
- 10 b) a tube bank located upstream of the slice chamber in the direction of flow of the stock, the tube bank comprising a plurality of straight tubes and the tubes being arranged in separate vertically spaced rows, the rows extending in a cross-machine direction, each tube having an upstream inlet end into which stock is intended to enter the tube and a downstream outlet end from which stock is intended to pass into the inlet of the slice chamber, the tube bank forming a passage through which stock is intended to pass from the upstream inlet end of the tubes to the inlet of the slice chamber, said passage having a straight main direction of flow of the stock which coincides with the straight main direction of flow of the stock in the slice chamber so that all the way from the upstream inlet end of the tubes to the downstream outlet of the slice chamber, the stock will flow in one and the same straight main direction of flow,
- 20 c) in the slice chamber, at least one machine-wide separator vane subdividing the slice chamber for the production of multilayer fibrous webs, said at least one separator vane extending in the direction of flow of the stock and having a thickness in the vertical dimension and an upstream end and a downstream end, said at least one separator vane having, from its upstream end to its downstream end, a decreasing thickness in the vertical dimension and, at its downstream end, a thickness in the vertical dimension which is less than 0.7 mm and said at least one separator vane having a stiffness in a cross machine direction which is, on average, at least 180 times greater than the stiffness of a 1 mm thick reference plate having a modulus of elasticity of 2100 MPa and which, on 7/10 of its length from its upstream end to its downstream end has a stiffness in a cross machine direction which is at least 35 times greater than the stiffness of a 1 mm thick reference plate having a modulus of elasticity of 2100 MPa where stiffness is defined as
- 35
$$S = Eh^3/12(1-\nu^2),$$

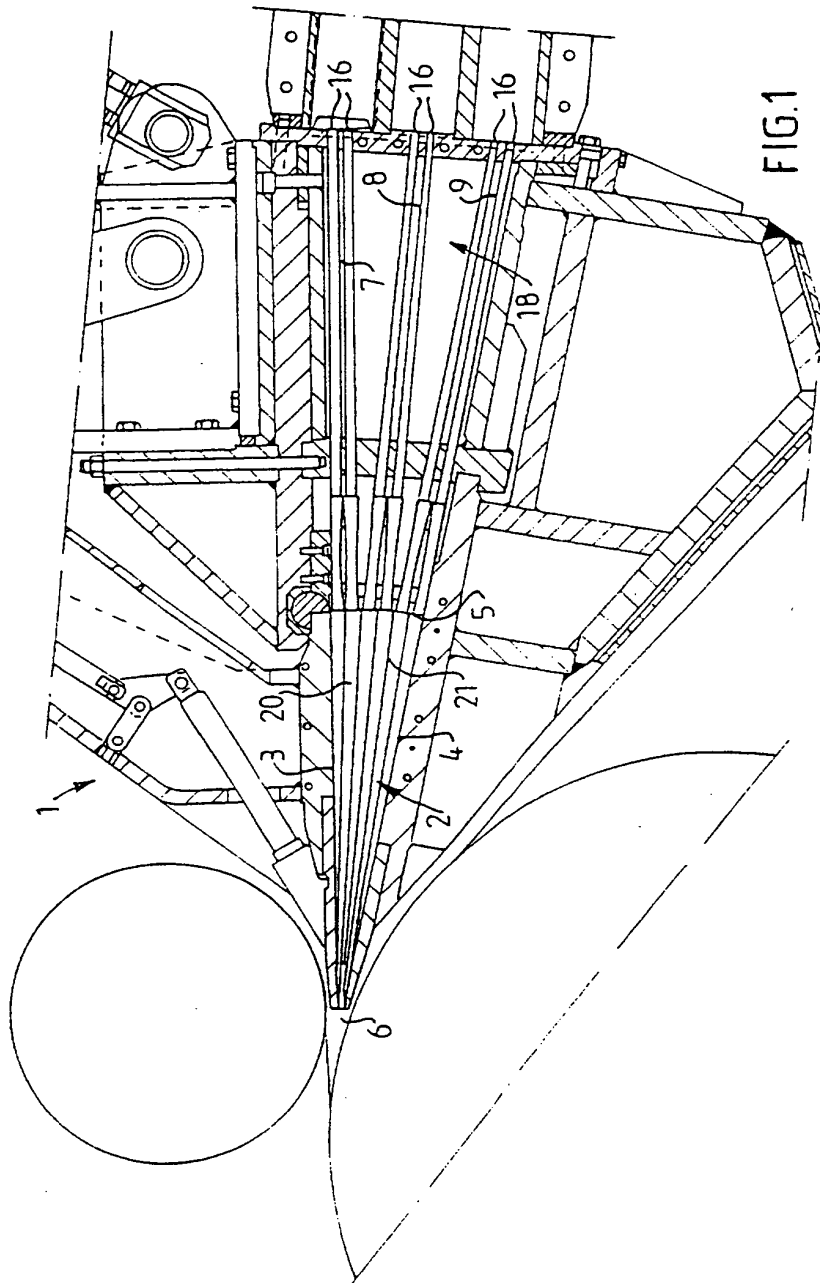
where S is separator vane stiffness, E is modulus of elasticity of the separator vane material, h is separator vane thickness and ν is the Poisson ratio for the material of the separator vane,

- 5 d) in the slice chamber, a plurality of machine-wide turbulence generating elements extending in the direction of flow of the stock, the turbulence generating elements having an upstream end and a downstream end, the upstream end of each turbulence generating element being interposed between the vertically spaced rows of tubes in a tube bank and fixed between said rows.
- 10 2. A multilayer headbox according to claim 1, wherein said at least one machine-wide separator vane is made of glass fiber reinforced epoxy resin and is tapered all the way from its upstream end to its downstream end such that its thickness in the vertical dimension decreases continuously from its upstream end to its downstream end.
- 15 3. A multilayer headbox according to claim 1, wherein said at least one separator vane is divided into an upstream section of constant thickness in the vertical dimension and a downstream section which is tapered such that its thickness decreases in the direction of flow of the stock and where the upstream section has an upstream end and a downstream end and the downstream section has an upstream end and a downstream end and where the upstream end of the downstream section is fixed to the downstream end of the upstream section and where the upstream end of the downstream section has a thickness in the vertical dimension which is less than the thickness in the vertical dimension of the upstream end such that, at the point where the upstream section is fixed to the downstream section, there is a machine-wide step.
- 20 4. A multilayer headbox according to claim 2, wherein said at least one machine-wide separator vane has a surface smoothness smaller than or equal to $0.4 \mu\text{m}$.
- 25 5. A multilayer headbox according to claim 3, wherein the downstream section has a surface smoothness smaller than or equal to $0.4 \mu\text{m}$.
- 30 6. A multilayer headbox for a papermaking machine comprising:
- 35 a) a slice chamber having an upstream inlet where stock is intended to enter the slice chamber and a downstream outlet through which stock is intended to pass from the slice chamber to a subsequent forming section of the papermaking machine, the slice chamber having a straight main direction of flow of the stock from the inlet of the slice chamber to the outlet of the slice chamber, the slice chamber further

having a top wall and a bottom wall, the top and bottom wall converging in the straight main direction of flow of the stock,

- 5 b) a tube bank located upstream of the slice chamber in the direction of flow of the stock, the tube bank comprising a plurality of straight tubes and the tubes being arranged in separate vertically spaced rows, the rows extending in a cross-machine direction, each tube having an upstream inlet end into which stock is intended to enter the tube and a downstream outlet end from which stock is intended to pass into the inlet of the slice chamber, the tube bank forming a passage through which stock is intended to pass from the upstream inlet end of the tubes to the inlet of the slice chamber, said passage having a straight main direction of flow of the stock which coincides with the straight main direction of flow of the stock in the slice chamber so that all the way from the upstream inlet end of the tubes to the downstream outlet of the slice chamber, the stock will flow in one and the same straight main direction of flow,
- 10 c) in the slice chamber, at least one machine-wide separator vane subdividing the slice chamber for the production of multilayer fibrous webs, said at least one separator vane extending in the direction of flow of the stock and having a thickness in the vertical dimension and an upstream end and a downstream end, said at least one separator vane having, from its upstream end to its downstream end, a decreasing thickness in the vertical dimension and, at its downstream end, a thickness in the vertical dimension which is less than 0.7 mm and said at least one separator vane having a stiffness which is, on average, at least 36 Nm and which for at least 7/10 of its length has a stiffness of at least 7 Nm where stiffness is defined as
- 15
$$S = Eh^3/12(1-\nu^2)$$
- 20 where S is separator vane stiffness, E is modulus of elasticity of the separator vane material, h is separator vane thickness and ν is the Poisson ratio for the material of the separator vane,
- 25 d) in the slice chamber, a plurality of machine-wide turbulence generating elements extending in the direction of flow of the stock, the turbulence generating elements having an upstream end and a downstream end, the upstream end of each turbulence generating element being interposed between the vertically spaced rows of tubes in a tube bank and fixed between said rows.
- 30

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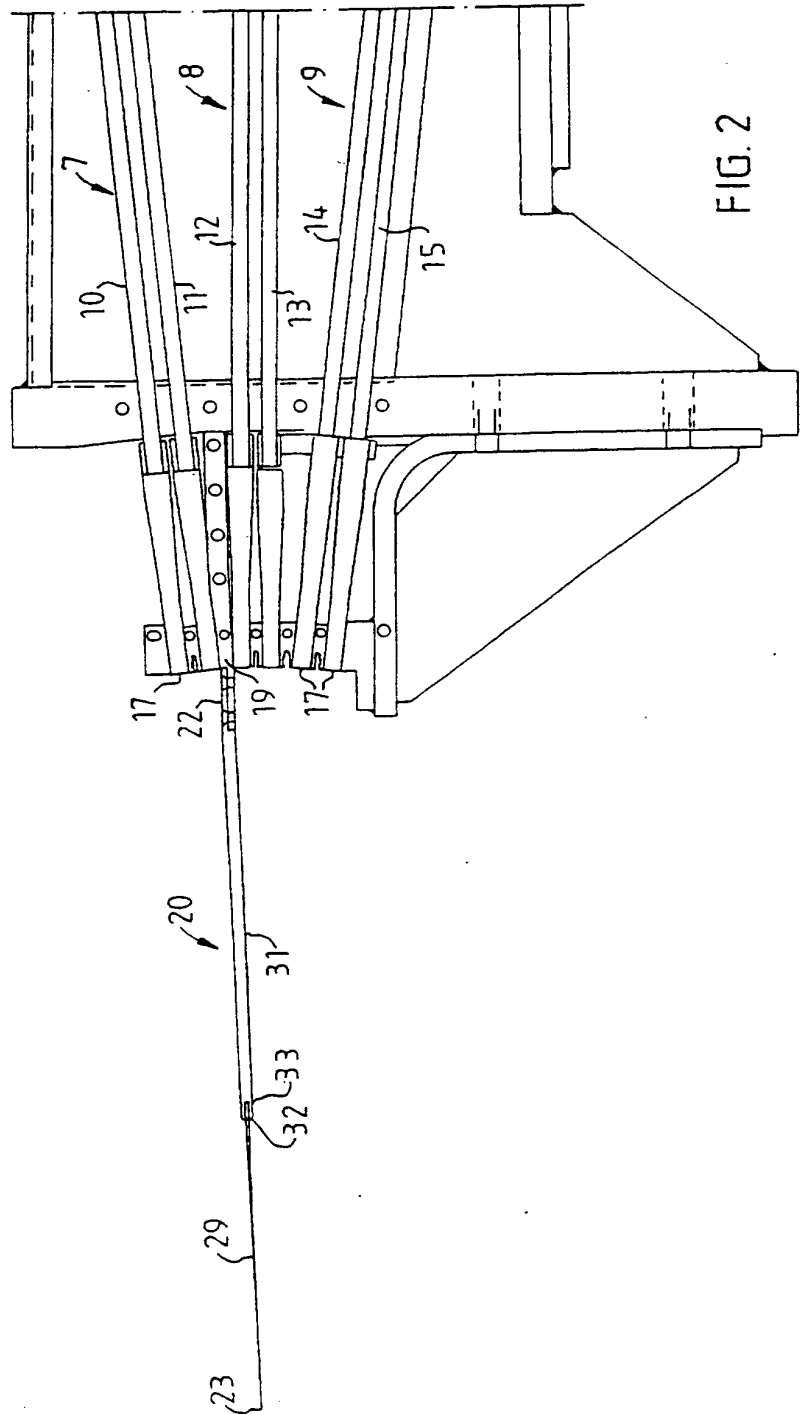


FIG. 2

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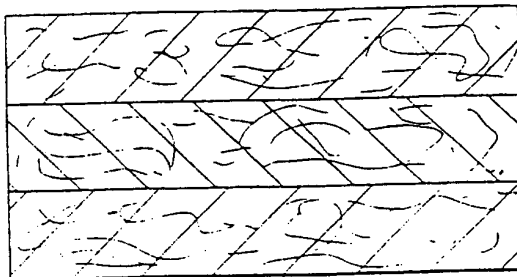


FIG. 3

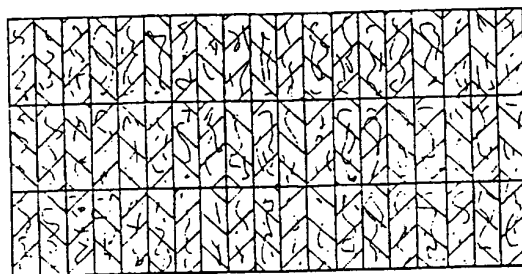


FIG. 4

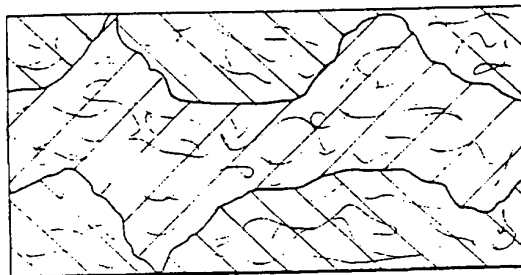
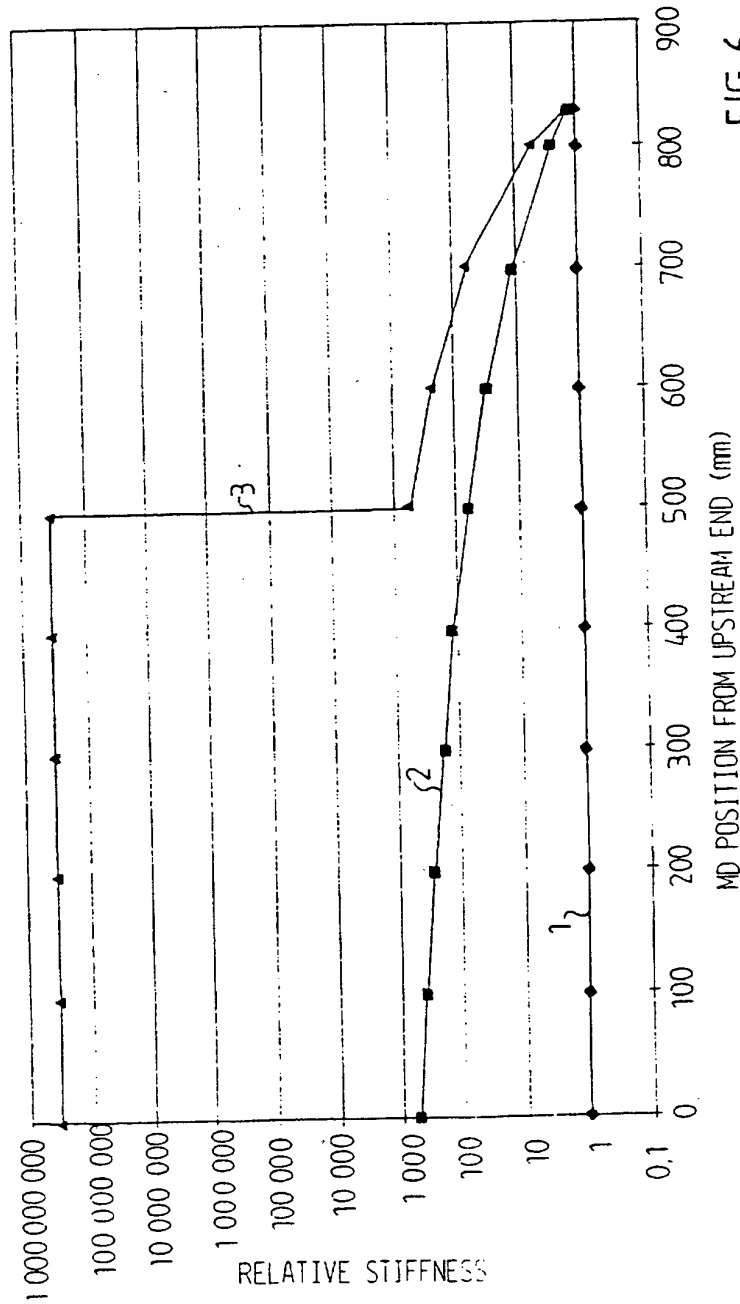
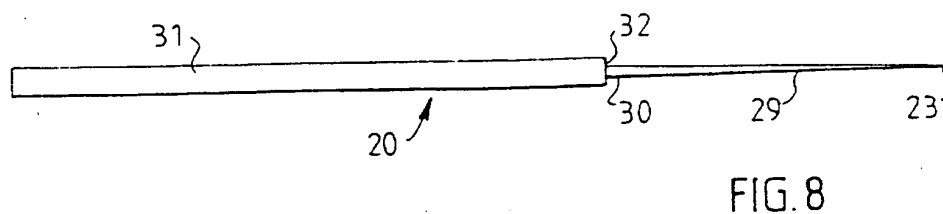
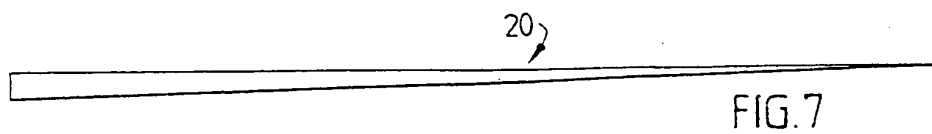


FIG. 5

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